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ABSTRACT

It is well established that Web-based courseware must not restrict itself to the mere delivery of instructional material, but must be grounded in some sound model of instruction and learning. This paper discusses one such model, based on the best of instructional design principles and tries to overcome two of the most serious problems that are being faced in the process of introducing interactive Web-based learning, namely disorientation and cognitive overload. Whereas the emphasis in a lot of recent work has been on digital technology reuse, the emphasis is on core aspects of the content development process. The principal contribution is an intuitively clear iconic notation that can be used to templatize and thus simplify the task of educational content development. The paper briefly describes the evolution of this model, the experimental effort to evaluate this model and the courseware development process that was adopted. (Contains 13 references.) (Author)

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A Model Driven Process for Web-based Instructional Content Development

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Abstract: It is well established that WWW-based courseware must not restrict itself to the mere delivery of instructional material, but must be grounded in some sound model of instruction and learning. This paper discusses one such model, based on the best of instructional design principles and tries to overcome two of the most serious problems that are being faced in the process of introducing interactive web-based learning, namely disorientation and cognitive overload. Whereas the emphasis in a lot of recent work has been on digital technology reuse, our emphasis is on core aspects of the content development process. Our principal contribution is an intuitively clear iconic notation that can be used to templatize and thus simplify the task of educational content development. We briefly describe the evolution of this model, the experimental effort to evaluate this model and the courseware development process that was adopted.

Present Web-based Learning Scenario

Traditional learning is premised on linear learning, while current brain research finds that learning is nonlinear and relates to interrelations of feedback loops in a holonistic total[Muhammad, 2000]. The World Wide Web can make nonlinear learning much easier than textbook/traditional curricula. Thus web-based learning is widely acclaimed to bring in student-centric, self-paced instruction. However, many of the courses offered on-line and much of the course material that is on-line do not cater to these adjectives. Typically, courseware development is done by translating an existing lecture format course into an HTML document. The traditional learning model, which is predominantly instructor centric, is followed, albeit with far too many inter-linkages (hyperlinks) in the content. There is no real structuring or freedom for the students to choose their path meaningfully. One serious problem in learning that arises due to such ad-hoc non-linearity in content is that of disorientation. It refers to users not knowing where they are, where they have been, or how to get to where they want to go in hypermedia space. This results in a learner picking up disjointed knowledge with many gaps and often wasted energy in duplicate learning [Murray *et al*, 2000].

Another serious problem is that of cognitive overload [Murray *et al*, 2000]. This refers to learners being overwhelmed or confused by the options available to them in multi-path, multi-tool environments such as those provided by hypermedia courseware. This is primarily due to discontinuous narrative caused by breaks in didactic or dialogical flow of the matter itself and improper conceptual flow of ideas or concepts.

Learning object, a digital resource that supports learning, is the current instructional technology leader designed to address the above problems [Wiley, 2000, Longmire, 2000]. However it seems unfortunate that commercial considerations have forced premature focus on maximizing reusability, adaptability, rapid-prototyping,

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scalability and other such mass production aspects, peripheral to the core goal of learning itself [Greenberg, 2000].

Requirements of a Web Learning Environment

Ausubel maintained and subsequent researchers [French, 1999] have strongly supported that the most important factor in what one learns is often what one knows. Interactive web-based learning, one in which the learner is treated as a co-discoverer of knowledge and asked to work collaboratively, has the potential to capitalize on an adult learner's prior knowledge and experience in a way that traditional approaches have often failed to do.

Thus any web based learning environment must promote:

1. Integrative knowledge building, in a sense that recognizes the learner's existing knowledge base and links to it the new knowledge components as the learning progresses.
2. Customization, which, at the least, offers to a learner choices of meaningful learning paths, styles and pace of learning. A technologically advanced model can also include learner profile (or even build learner profile as learner progresses in her learning) and offer appropriate options, most suited to the profile.
3. Interactive content delivery that engages students continuously. A good environment should also have the facility to establish a contact with peer learners and the facilitator / teacher.

Instructional Design (ID) Principles - as applicable to web based instructions

Given the two serious problems described above, we propose a six-step approach for instructional content development adopting the best of instruction design principles:

1. Define a semantically meaningful unit of instruction – we will call it Concept.
2. Design an appropriate structure of concepts, which connect them in a logical way to ensure that the body of knowledge evolves as the learner progresses with the learning. We can adopt a tool like a Concept Graph for this purpose.
3. Design the right level of granularity of concepts.
4. Define a classification for the concepts.
5. Determine learning levels.
6. Select the right learning primitives to provide the desired learning experiences.

We shall discuss these in some more detail below.

Smaller and semantically meaningful unit of instruction: It is well established that the unit of a typical lecture/chapter, covering a fairly large chunk of content, cannot be easily related to concepts. It suffers from the disadvantages of long durations, unacceptably long attention spans for self-paced learning, and also from the fact that testing for understanding can be done only at unit boundaries [Joyce and Weil, 1996]. Hence educationists and early work in ITS have proposed a smaller unit of instruction. We will denote this by the term concept, a notion we largely base on Bloom's model for Mastery Learning. "A concept is a semantically meaningful unit of instruction with a specific intent type and a matching instruction and evaluation type." [Bloom, 1956]

Concept Graph: This is a simple structure representing prerequisite relationships amongst concepts [Cauano *et al*, 2000].

Granularity of Concept: A concept must have a simple, short and clearly stated learning objective. Enforcing this during review and evaluation will help ensure the right granularity for a subject. Finer granularity provides greater opportunities for learner control. [Quinn, 2000]

Classification of Concepts: Apart from specific intent type, the notion of concept has the other aspect of matching instruction and evaluation type. Content defined for learning a concept should match its intent. The idea is that, a learner, having decided upon the learning goals, can choose a matching type of instruction unit. This leads to concept classification-based on Merrill's work [Merrill, 1999].

1. Facts / Part-Of: Concepts in this category match the instructional objective concerned with the "WHAT?" aspect. Concepts consist of arbitrary pieces of information. Examples are facts about a particular event like a sports match, a particular object like a modem, a mouse, etc.
    i. Kind-Of: Here we are concerned with the classification aspect of the knowledge to be learned, identifying relevant examples and non-examples. Examples are categorizing various animals into different species, categorizing natural phenomenon, etc.
2. Rule-Using/Procedural: In these, the instructional objective is concerned with "HOW" to do some thing. A procedure is an ordered sequence of steps for accomplishing some goal. Examples of such concepts are adding fractions, operating a machine, sending e-mail, etc.
3. Principle/Problem solving: This category is concerned with prediction and explanation of "WHY" things happen in the world. They are cause-and-effect, correctional, or constraint relationships. A principle is a relation between two or more changes. Such concepts will have the problem-solving aspect as their main objective. Examples of such concepts will be "an increase in price causes decrease in demand", "plants grow from a seed to a seedling to a plant", etc.

Since this classification basically focuses on the intended objective of learning units, one significant outcome is that the environment can be designed to adopt pedagogically correct behavior appropriate to a learner's choice of learning unit type. For example 'Part-of ' type learning can occur if information is communicated in a form that remains accessible to the learner, say, a list of directions, throughout an act of learning [Gagne *et al*, 1992]

Learning levels: The issue of depth of learning or performance level leads to identification of learn ing levels as follows:

1. Memorize: Performance at this level merely requires the learner to search memory in order to reproduce or recognize information presented.
2. Understand: This level requires the learner to identify the examples and non-examples and their attributes in order to categorize and classify the data presented. Performance at this level promotes comprehension.
3. Apply/Use: This requires that the learner be able to apply the knowledge within a context, where it is clear that the piece of knowledge is applicable.
4. Problem-Solve: This requires the deepest level of assimilation. This level requires that the learners recognize if and when a piece of knowledge is applicable, and then apply it correctly.

Theoretically any concept type can be learned at any learning level.

Learning primitives: Learning a concept is a collection of several types of learning experiences such as reading/listening to instructions, exploring the subject matter, solving problems and many more. In a teacher centric environment a well designed and delivered lesson takes care of all these aspects. But in a learner centric environment the system has to provide these experiences explicitly by the means of various learning resources. We visualize these resources as building blocks enabling a learner to build her knowledge for a concept and term them as learning primitives, somewhat similar to Cisco's RIOs [Cisco, 1999]. Each learning primitive gives the learner a suitable learning experience (at required time, of suitable knowledge type, at required learning level and in desirable media type). Various learning primitives [Gharpure & Mudur, 2000] have been identified and these can be assembled into a concept. These include statement of objective, entry test, instruction, demonstration, simulation etc. More can be thought of. A primitive's contents are developed as a combination of interactive media elements and presented depending upon domain, environmental capabilities and learner preference.

Thus a model can now be evolved based on the ID principles as discussed above.

Learning Unit Class Model

A Learning Unit Class (LUC)[1] is the collection of learning primitives required to deliver learning of a particular concept for a combination of learning level and knowledge type. Content for any subject is a directed

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[1] In order to avoid any possible confusion/patent/copyright infringement, we have intentionally moved away from using already in-use terms like reusable learning object, knowledge object, educational object etc. for this or reusable information object for learning primitives. It also helps us emphasize the fact that our focus is on the creation of the content. Further

graph of LUC nodes, where arcs denote pre-requisite knowledge. The arcs could move across different subject matters. We have designed an intuitively simple iconic notation for different LUCs, which are shown in Table 1.

As an example, for teaching a procedural concept at the level of application, a demonstration will be very useful, while for teaching the same at the level of problem solving, an interactive simulation might work much better. Thus for each of learning unit class a template[2] (as a set of primitives) can be generated (*cf* Fig. 1 for an example). The real challenge before an instructional designer now becomes that of identifying suitable concepts, their learning levels, specification/design of various learning primitives for communicating the concept and finally the concepts into seamless and logical flow content.

CONCEPT LEVEL — TYPE	MEMORIZE	UNDERSTAND	APPLY	PROBLEM SOLVE
PART-OF /FACT OBJECTIVE—	 Recall or state fact	 Recognize/Identify fact	 Use/apply fact in carrying out task	 Identify required fact and use/apply in task
KIND-OF CLASSIFICATION OBJECTIVE—	 Recall examples / non-examples	 Recognize example / non-example;	 Use correct example.	 Identify example in current context and use
PROCEDURE OBJECTIVE—	 Recall rule / procedure	 Select / identify the appropriate procedure	 Use/apply a procedure/skill	 Trouble shoot, adapt variant to solve problem
PRINCIPLE OBJECTIVE—	 Recall principle	 Identify scenario in which principle is applicable	 Apply the principle in a known scenario	 Identify and Apply the principle in an unknown scenario

Table 1: Iconic Notation for LUCs

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these could be suitably wrapped into standard reusable learning components, whenever such technological packaging is demanded.

[2] Because of support for definition of such templates, this model has the scope to be developed as an integrated environment for content creator, offering a matching toolset for each template to create course content based on ID principles.

LUC TYPE	OBJECTIVE	ENTRY TEST	INSTRUCTION	ILLUSTRATION	DEMONSTRATION	EXPLAINATION	EXPLORATION	SIMULATION	EXAMPLE	NONEXAMPLE	REMINDER	REFERENCE	EXERCISE	HINT	EVALUATION	WORKPLACE	ADDRESS BOOK	ASK QUESTION	FEEDBACK
	R	R	R	R	R	R	O	O	O	O	R	R	R	R	R	R	R	R	R

Legend: R: REQUIRED; O: OPTIONAL

Figure 1: A template for a Learning Unit Class (type: procedure, level: apply)

The Experiment and the Process Adopted

This experiment, conducted by one of the authors, Professor Prachi Gharpure involved developing the web-based content for a course titled 'Introduction To Internet ', paper IV for MECTA (Master of Education with Computer Application), a post graduate degree program at SNDT University, Mumbai. The content covered the entire syllabus for the course, as defined by the SNDT University. The course is being taken by MECTA students as we write this paper and the results of an on-going evaluation of the content will be available for further study by June 2002. For review purposes, part of this course is temporarily uploaded on http://www.sndt.netfirms.com/Faculties/Education/DET/Online%20Learn.html. The model-based process adopted is briefly presented in Table 2.

Phase	To be Executed By	Tasks
I May alternate with phase 2 in the process.	• Content Expert • Instructional Designer	1. Identify concepts covering syllabus 2. Map concepts into graph with pre-requisite links[Tellis, 2001]. Fig. 2 shows a first level graph whose nodes get exploded as the learning progresses. 3. Define LUC consisting of learning primitives (guided by template) most suited to meet the learning objectives of the concept. Fig. 3 shows the screen shot for one such LUC
		Example Tools: concept graph editors such as http://www.inspiration.com/ http://users.edte.utwente.nl/lanzing/cm_home.htm
II May alternate with phase 2 in the process.	• Instructional Designer • Software Developer • Visual Designer	Development of templates for different LUCs.
		Example Tools: Spreadsheet, Presentation, Word Processor, etc. (This step in the process adds value to the creation process in terms of consistent layout and look and feel throughout the learning experience. This is very important because the learner can navigate smoothly as she develops a certain amount of familiarity and comfort level in navigation, interaction and knowledge assimilation processes.)
III	• Instructional Designer • Visual Designer • Software Developer	Creation of interactive content
		Example Tools: Web content authoring/publishing tools that enable creation and integration of various components. (This step in the process is the actual content creation process .The process should consider issues like Learner control, Media selection, Interface Consistency, Internet issues etc.)
IV	• Software Developer	Integration into courseware and web based education delivery environment
		Example Tools: E-Learning Management Systems, for an overview of such systems http://www.ncst.ernet.in/~vidyakash/portal/tools.shtml
V	• Content Expert • Instructional Designer • Learners from a representative community	Courseware review Specification of Evaluation criterion
		Example Tools: Web-based feedback forms, statistical analysis tools etc.

Table 2: Model based process for courseware development

Conclusion

A model driven content development process, rooted in instructional design, offers excellent scope for developing an integrated system that guides courseware developers through templates to create potentially high quality content for individualized learning. The principal contribution of this paper is one such model, with an intuitively simple iconic notation. The model has been tested by actually creating content for a postgraduate course which is presently live. The content evaluation phase is currently on for evaluating the results for this model driven process both from instructional design and from learner perspectives.

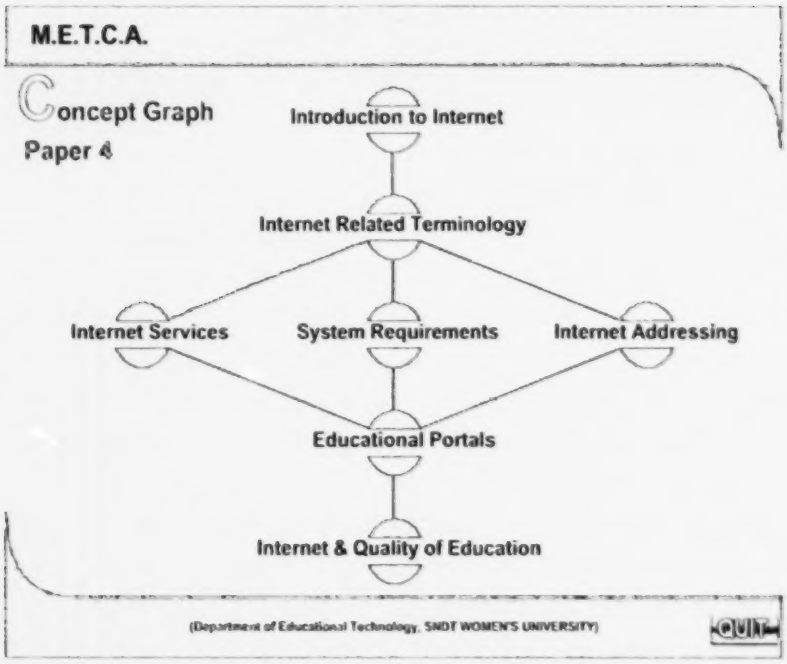

Figure 2: Concept Graph

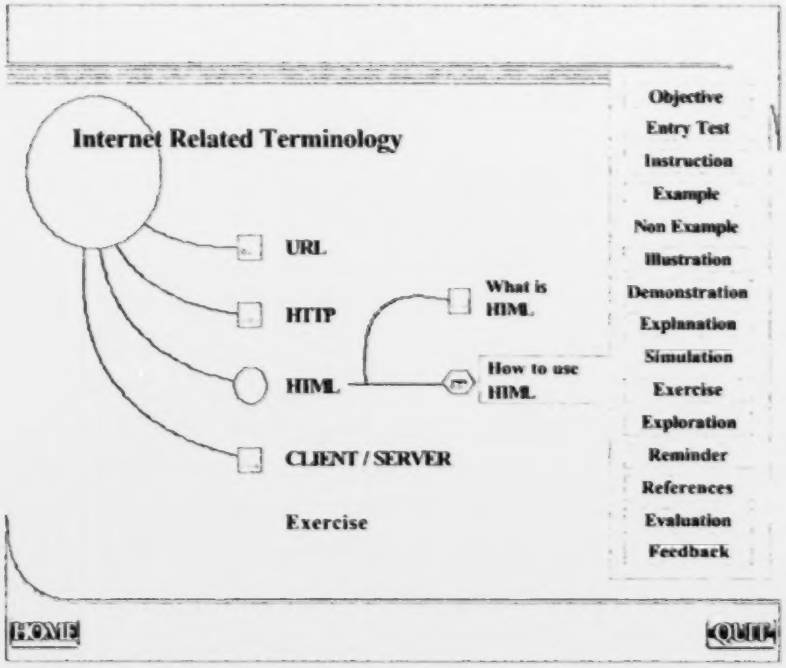

Figure 3: LUC Example

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